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In aerial combat maneuvers (ACMs), at Luke AFB, AZ, eight pilots flew their two F-15 aircraft against nine pilots in three F-106 aircraft. A total of nine flights, consisting of 23 ACMs, were accomplished in 5 successive days. The degrees of fatigue, stress, and sympathetic activity were quantified using both subjective analyses and the biochemical constituents in the urine of the pilots of the F-15 or F-106. Biochemical indicators, reported per 100 mg creatinine, included: epinephrine, norepinephrine, 17-OHCS, urea, inorganic phosphate, sodium, potassium, and sodium/potassium ratio. The F-106 pilots exerted more

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relative effort than did the F-15 pilots--effort which appeared to be associated with high-G experience. Both groups of pilots were equally fatigued following ACMs; however, only the fatigue of the F-106 pilots was directly correlated with the length of the ACM. Sympathetic and stress responses during the ACM--similar for both groups of pilots--showed postflight increases of 54% in epinephrine, 19% in norepinephrine, and 20% in 17-OHCS over preflight values, thus suggesting a moderate stress response. Resting levels of these same indicators, for days the pilots did not fly and for pre-ACM values, were similar but higher than control values previously reported for other stressful activities. By late afternoon, postflight values for these indicators had returned to near-preflight levels.

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Stress Responses of Pilots Flying High-Performance Aircraft During Aerial Combat Maneuvers

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BURTON, R. R., W. F. STORM, L. W. JOHNSON, and S. D. LEVERETT, JR. *Stress responses of pilots flying high-performance aircraft during aerial combat maneuvers.* Aviat. Space Environ. Med. 48(4):301-307, 1977.

In aerial combat maneuvers (ACMs), at Luke AFB, Az, eight pilots flew their two F-15 aircraft against nine pilots in three F-106 aircraft. A total of nine flights, consisting of 23 ACMs, were accomplished in 5 successive days. The degrees of fatigue, stress, and sympathetic activity were quantified using both subjective analyses and the biochemical constituents in the urine of the pilots of the F-15 or F-106. Biochemical indicators, reported per 100 mg creatinine, included: epinephrine, norepinephrine, 17-OHCS, urea, inorganic phosphate, sodium, potassium, and sodium/potassium ratio. The F-106 pilots exerted more relative effort than did the F-15 pilots—effort which appeared to be associated with high-G experience. Both groups of pilots were equally fatigued following ACMs; however, only the fatigue of the F-106 pilots was directly correlated with the length of the ACM. Sympathetic and stress responses during the ACM—similar for both groups of pilots—showed postflight increases of 54% in epinephrine, 19% in norepinephrine, and 20% in 17-OHCS over preflight values, thus suggesting a moderate stress response. Resting levels of these same indicators, for days the pilots did not fly and for pre-ACM values, were similar but higher than control values previously reported for other stressful activities. By late afternoon, postflight values for these indicators had returned to near-preflight levels.

The research reported in this paper was conducted by personnel of both the Crew Technology Division, USAF School of Aerospace Medicine, Brooks AFB, Tx, and the Operation, Test, and Evaluation Squadron, Luke AFB, Az.

The voluntary informed consent of subjects used in this research was obtained as required by Air Force Regulation 80-33.

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LITTLE IS KNOWN regarding the physiologic stress of pilots flying high-performance aircraft, although the high G associated with these types of fighter aircraft is known to be stressful. Previous studies have examined the physiologic stress of pilots of aircraft without high sustained G capability; e.g., pilots flying the F-104, or F-100 aircraft (3,7,10). These studies dealt specifically with the stress of long-duration flights at 1 G or the stress of low-G supersonic intercept missions.

For 1 week at Luke AFB, Az, in April 1975, pilots from two squadrons were involved in aerial combat training. The F-15 Operational Test and Evaluation

(OT&E) Squadron from Luke AFB flew the F-15 air superiority aircraft capable of developing high sustained G (HSG)—of 6 G and more for more than 15 s (1)—in an aerial combat maneuver. The 87th Fighter Intercepter Squadron from K. I. Sawyer AFB, Mi., flew the F-106 which, like the F-15, is capable of developing HSG.

During this week of ACT, physiologic stress analyses were performed on the pilots of both aircraft on a daily flight-by-flight basis, and the results of that study are reported here.

MATERIALS AND METHODS

On the Saturday before the week of ACT, three F-106 aircraft were flown into Luke AFB from K. I. Sawyer AFB. For our study, nine pilots (with an average of 1200 h of experience in the F-106) flew these three F-106 aircraft against eight OT&E pilots (with an average 40 h of experience in the F-15) who used two F-15 aircraft.

Each pilot had considerable ACM experiences—an average of 2500 h in fighter aircraft—averged 33 years old, and was judged to be in good-to-excellent physical condition. Standard USAF CSU (5-bladder type) anti-G suits were worn by all of the pilots during all of the flights, and standard suit-inflation schedules were used (1.5 psig, beginning at 2 G).

Beginning Monday and continuing through Friday, ACT involved, if possible, one flight each morning and one flight each afternoon. A flight was composed of a minimum of two aircraft and a maximum of five—frequently an extra F-106 was involved in an ACM; e.g., two F-15s against three F-106s. The maximum airspeed used by the F-106 was approximately Mach 1.4, and the F-15 was limited to $<$ Mach 1. Also, both aircraft were acceleration-limited to approximately 7 G.

A single flight could involve only one or as many as 5 ACMs using inflight refueling over the test range. A total of nine flights, consisting of 23 ACMs, were accomplished during the week.

Physiologic responses associated with flying high-performance aircraft were determined via urinalyses and subjective data. Of particular, but not exclusive, interest to us in this study were: pilot fatigue and effort; sympathetic responses; and physiologic stress resulting from repeated exposures to long-duration ACMs of relatively high G.

Two or three urine samples were obtained from each pilot every day that he flew. The first sample was taken preflight usually in the morning. The second sample was made available as soon as possible postflight. The third urine sample was always the second urination postflight. Occasionally a urine sample from a nonflying control was taken in the morning on days that the pilot was not scheduled to fly and did not fly an ACM.

Each urine sample was collected in a plastic bottle, acidified with diluted HCl (1.6 N) acid, identified with a label (hour, date, pilot), and immediately refrigerated for a maximum of 4 h. Then, the sample was frozen until analyzed by the Environmental Sciences Division, USAF School of Aerospace Medicine (SAM), Brooks AFB, Tx.

The following substances were quantitatively identified in the urine: epinephrine, norepinephrine, 17-hydroxycorticosterone (17-OHCS), creatinine, uric acid, urea, potassium, sodium, and phosphate. Methods used in these analyses have been reviewed by Hale *et al.* (6). All values are reported per 100 mg creatinine. Creatinine excretion by the body is quite constant and is frequently used as a "marker" to relate to lean body mass.

The subjective fatigue analysis was based on a fatigue checklist given to each pilot for completion before and after each flight. Each morning, the pilot's state of rest was also subjectively determined with a simple questionnaire. After each flight, the amount of effort used during the maneuvering aspects of the ACMs was estimated by the pilot using a minimum-to-maximum exertion scorecard (2).

During the debriefing of each flight, the pilot approximated the following aspects of ACM: a) Peak G and duration in seconds at peak G; and (b) duration and average G of the entire ACM. Also, the pilot was queried regarding any serious equipment failure during the flight which might have initiated additional physiologic stress.

RESULTS

ACM: A comparison of the ACMs, as flown by the F-15 and F-106 pilots, is summarized in Table I. The F-15 pilots, flying a more maneuverable aircraft, were exposed to slightly higher peak G than were the F-106 pilots. Also, the F-15 pilots remained at these peak-G levels more than twice as long. The reason for this is that sometimes more F-106s than F-15s were engaged in each ACM; e.g., a single F-15 pilot frequently had to combat two F-106s; and the F-15 always, and rapidly, became the aggressor.

Durations of ACM activities for both aircraft were identical, because an ACM was terminated after one of the aircraft was "shot down." However the mean G in ACM was significantly greater for the F-15 pilots—a function of the longer stay at peak G.

It appears, therefore, that the F-15 pilots were exposed to more Gs during the ACMs than were the F-106 pilots. This difference probably would have been greater had the limits on G and speed been removed from the F-15.

Effort: The mean effort exerted by the F-15 pilots, subjectively quantified on a scale of 0 (no effort) to 10 (maximum effort), for the nine flights was 5.69 ± 0.36 (mean $\pm$ S.E.). The effort score for the F-106 pilots was significantly greater: 7.13 ± 0.31 ($p < 0.01$; Student's t-test). This information is interesting in that, although the F-15 pilots pulled more G, they exerted less *relative* effort.

This apparent inconsistency may be explained by the fact that the effort required of people to tolerate G in a specific situation is related to their known maximum effort—and people generally are not aware of their maximum effort potential until they have been sufficiently challenged. Regarding G tolerance, each of the pilots was asked to *estimate* his *maximum* duration of

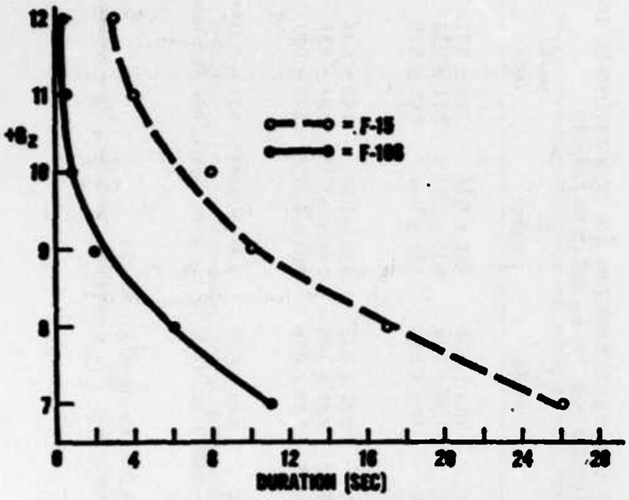

Fig. 1. Estimates of the maximum duration of acceleration the pilots could tolerate at each G level. The mean response of the F-15 pilots (n = 8) is represented by the open circle—the F-106 pilots (n = 7), by the closed circle.

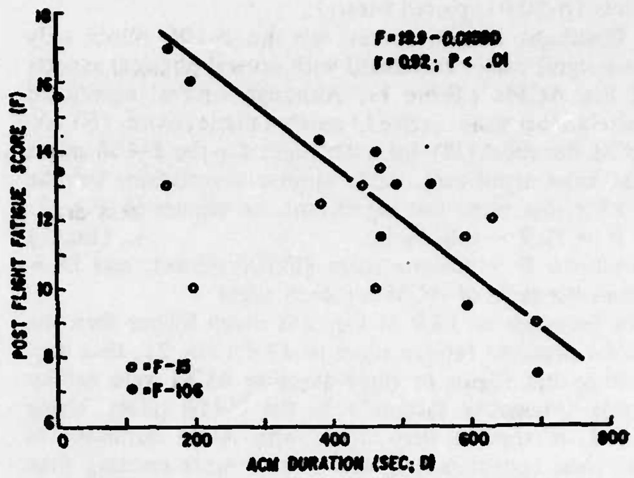

Fig. 2. The duration of all of the ACMs of each flight compared with the mean fatigue scores of the F-15 (open circle) and F-106 pilots (closed circle) for each flight. The duration of ACM is highly correlated with fatigue score for the F-106 pilots ($r = 0.92$; $p < 0.01$). The same correlation for the F-15 pilots is not significant. The fatigue scores at 0 duration ACM are preflight mean values for the appropriate pilot group.

tolerance to various levels of high G. The results of this query are shown in Fig. 1. Although both pilot populations had similar hours of flying experience in fighter aircraft, the F-15 pilots were aware of having higher G tolerances for they flew an aircraft with higher G capability and, from experience, knew that they could tolerate this G environment for longer periods. Consequently, the effort exerted by the F-15 pilots in this study is less than that of the F-106 pilots relative to their "known" maximum effort. Interestingly, even the F-15 pilots estimated their G tolerance capabilities low; e.g., with proper training on the centrifuge, man can tolerate $+9\ G_z$ for 45 s or $+8\ G_z$ for 60 s (1,9).

The effort score of 5.69 exerted by the F-15 pilots was considerably less than that of approximately 9 for F-16 pilots, on the basis of three exposures on the SAM centrifuge to 95 s of variable G profiles—having a mean of 4.8 G—with two epochs of 8 G per exposure (2). Although the mean ACM duration in seconds × G per flight in this study was 1878 G × s, whereas the centrifuge exposure was less at 1368 G × s, the F-16 pilots had to exert considerably more effort than the F-15 pilots to tolerate the centrifuge exposures. The higher peak-G epochs of 8 G in the centrifuge profile, as compared with mean peak-Gs of 5.8 in the F-15 ACMs, probably were a contributing factor in the high effort scores of the F-16 pilots riding the centrifuge.

Fatigue: Fatigue was subjectively determined, using a checklist from a maximum score of 20 (without fatigue) to a minimum score of 0 (maximum fatigue). The postflight mean (± S.E.) fatigue score for the F-15 pilots was 11.9 ± 0.80; and the F-106 pilots had a similar fatigue score of 12.5 ± 0.81 for the nine flights. Although the F-15 pilots exerted significantly less relative effort than the F-106 pilots, they were equally fatigued. A subjective fatigue score, however, is not related to past experience, such as the effort score, but is based on the person's feelings that day. There was not a significant correlation between effort and fatigue.

Although, postflight fatigue scores were similar for *both* pilot populations, postflight scores were significantly reduced from preflight values *only* for the F-15

TABLE I. A COMPARISON OF NINE FLIGHTS INVOLVING 23 ACMs FLOWN BY F-15 AND F-106 PILOTS (VALUES ARE MEANS ± S.E.).

ACTIVITY	PILOTS F-15	F-106	p <
Per Flight:			
Mean ACM duration (s)	447	447	—
Mean G × duration (G × s)	1878	1547	—
Per ACM:			
Mean ACM duration (s)	173 ± 11.3	173 ± 11.3	NS
Mean ACM G	4.1 ± 0.19	3.5 ± 0.11	0.01
Mean G × duration (G × s)	733 ± 68	605 ± 42	NS
Mean duration of peak G (s)	20.5 ± 2.17	8.9 ± 0.76	0.001
Mean peak G	5.8 ± 0.16	5.5 ± 0.12	NS
Max-min peak-G range	4.5 ± 7.3	4.0 ± 6.2	—
Peak G × duration (G × s)	111 ± 12	43.8 ± 4.3	0.001

NS = Not statistically significant ($p > 0.05$)

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pilots ($p<0.01$; paired t-tests).

Postflight fatigue scores for the F-106 pilots only were significantly correlated with several physical aspects of the ACMs (Table I). Although several significant correlations were derived, mean fatigue score (F) vs. ACM duration (D) for each flight for the F-106 pilots was most significant, while similar correlations for the F-15 pilots were not significant, as shown in Fig. 2:

$$F = 19.9 - 0.0159\,D \qquad \text{(Eq. 1)}$$

in which: F = fatique score (F-106 pilots); and D = mean duration of ACM for each flight.

The intercept of 19.9 of Eq. 1 is much higher than the actual preflight fatigue score of 13.4 (Fig. 2), thus suggesting that flights of short-duration ACM were exhilarating ("negative fatigue") to the F-106 pilots. Using Eq. 1, it appears that flights with ACM durations of less than approximately 400 s were more exciting than fatiguing to the F-106 pilots.

On the other hand, the postflight fatigue scores of the F-15 pilots were not significantly correlated with the duration of ACM. Also, the mean preflight fatigue scores were higher for the F-15 pilots (15.6) than for the F-106 flyers (13.4), although not significantly different (via Student's t-test).

A sleep survey, as already noted under "Methods", was taken for every pilot each morning of the day on which he was to fly ACM. Although both groups of pilots received approximately the same amount of sleep each night (group means of 7 h 36 min for the F-15 pilots, and 7 h 45 min for the F-106 pilots), the F-106 pilots more frequently had trouble falling asleep and did not rest as well as the F-15 group. These differences in the quality of sleep between groups were quantified and found to be statistically significant (via Student's t-test). Thus, sleeping difficulty in the F-106 pilots may have been the reason for their lower preflight fatigue scores.

Sympathetic Responses: Sympathetic activity during each flight was evaluated using pre- and postflight urinary epinephrine and norepinephrine levels. These values, for both pilot populations, are listed in Table II. No significant differences (Student's t-test) were found, between pilot groups, for any of the items of Table II. Consequently, for purposes of discussion, values for both populations were combined for all measures, both pre- and postflight.

A significant increase of 54% ($p<0.001$) in the output of epinephrine occurred during the flight for both pilot groups via paired t-tests. Also, a statistically significant increase ($p<0.01$) of 19% was found in norepinephrine by using the paired t-test.

Since the preflight values may have been influenced by anticipation of the approaching flight—as suggested by Debijadji *et al.* (3); and by Marchbanks *et al.* (7)—urine samples were also taken from the same pilots on days they did not fly ACM. These data are compared in Table III with those of control groups from other experiments by our laboratory, such as Hale *et al.* (5) and Marchbanks *et al.* (7), as well as with our preflight values from Table II. It appears that our ACM pilots, even on non-ACM days—usually nonflying days—do not have less sympathetic activity than on days they expect to fly maneuvers—and that these "resting" values are much higher than those found in three control groups, as reported by our laboratory in previous studies (Table III).

Comparisons of our data on resting and active sympathetic activity with those of other stress groups, as reported previously, are shown in Table IV. Once again, resting values are high for both epinephrine and norepinephrine. On the other hand, ACM activity is not associated with extremely high levels of either catechola-

TABLE II. COMPARISON OF URINARY CONSTITUENTS OF F-15 AND F-106 PILOTS, AND RELATIONSHIPS OF CONSTITUENTS TO AERIAL COMBAT MANEUVERS (ALL VALUES (MEAN ± S.E.) ARE EXPRESSED PER 100 mg OF CREATININE).

Group	N	E (μg)	NE (μg)	17-OHCS (μg)	Urea (mg)	PO_4 (mEq)	Na (mEq)	K (mEq)	Na/K ratio
					PREFLIGHT†				
F-15	14	2.32 ± 0.25	5.45 ± 0.55	391 ± 32.5	1045 ± 96	31.4 ± 4.26	10.6 ± 1.28	5.42 ± 0.56	2.08 ± 0.25
F-106	18	1.90 ± 0.18	4.65 ± 0.31	386 ± 33.1	1029 ± 64	25.9 ± 4.19	10.0 ± 1.19	5.29 ± 0.71	2.11 ± 0.22
All††	32	2.08 ± 0.15	5.00 ± 0.30	388 ± 23.0	1036 ± 54	28.3 ± 3.00	10.3 ± 0.86	5.35 ± 0.46	2.09 ± 0.16
					POSTFLIGHT—1†				
F-15	14	3.45 ± 0.29*	6.61 ± 0.60*	483 ± 33.5**	953 ± 91	19.7 ± 3.71**	9.91 ± 1.15	4.56 ± 0.50	2.20 ± 0.16
F-106	18	3.02 ± 0.23***	5.45 ± 0.32*	454 ± 30.6*	892 ± 61*	20.3 ± 4.50*	8.55 ± 1.05	3.69 ± 0.33**	2.34 ± 0.18
All††	32	3.21 ± 0.18***	5.96 ± 0.33**	467 ± 22.4**	919 ± 52**	20.1 ± 2.96***	8.83 ± 0.76	4.03 ± 0.29**	2.28 ± 0.12
					POSTFLIGHT—2†				
All††	15	2.26 ± 0.25	5.04 ± 0.80	428 ± 38.9	1021 ± 50	27.7 ± 6.60	8.89 ± 0.77	3.00 ± 0.28***	3.21 ± 0.34**

†Mean sampling times: Preflight = 0930 hours (2 h 30 min before flight); Postflight—1 = 1420 hours (1 h 10 min after flight); and Postflight—2 = 1600 hours (3 h 55 min after flight).

††Includes both F-15 and F-106 pilots.

* = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$ (paired t-testing; significant differences between pre- and postflight means).

N = samples per group; E = epinephrine; NE = norepinephrine; 17-OHCS = 17 hydroxycorticosteriods; PO_4 = inorganic phosphate; Na = sodium; K = potassium; and Na/K = sodium:potassium ratio.

TABLE III. COMPARISON OF THREE PREVIOUS CONTROL GROUPS (1-3) OF UNSTRESSED SUBJECTS WITH TWO OF THE PRESENT GROUPS (4-5).

Group	N	E	NE	17-OHCS	UREA	PO_4	Na	K	Na/K
(Previous study)									
				UNSTRESSED CONTROLS					
1***	10	0.81	3.78	293	1092	—	7.45	2.95	2.98
				POSTFLIGHT CONTROLS					
2***	1000-2200	0.73	3.39	214	1134	—	8.62	4.10	2.55
				NONFLYING DAYS (F-100/F-104 pilots)					
3††	12	0.25	1.23	280	920	30.0	8.1	3.3	2.4
(Present study)									
				NON-ACM DAYS (F-15 AND F-106 PILOTS)					
4	8	2.48	6.35	488	1301	25.3	15.1	5.93	3.14
		±0.32**	0.49	40	156	4.23	2.23	1.28	0.62
		+199*	+69	+67†	+24†	—	+96	+92	+5
				PREFLIGHT CONTROLS (refer to Table II)					
5	32	2.08	5.00	388	1036	28.3	10.3	5.35	2.09
		+157*	+32	+32	−5	—	+38	+1	−30

*Δ% from group 1; N = number of samples per group.
**± S.E.
†significantly different from eight subjects of the preflight controls (Group 5) using paired t-test.
***Hale *et al.* (5).
††Marchbanks *et al.* (7)

TABLE IV. COMPARISON OF URINARY SYMPATHETIC ACTIVITY BETWEEN VARIOUS GROUPS OF SUBJECTS ASSOCIATED WITH FLYING AIRCRAFT (ALL VALUES ARE EXPRESSED PER 100 mg OF CREATININE).

Group	Epinephrine		Norepinephrine		Reference
	(Rest)	(Active)	(Rest)	(Active)	(No.)
Pilot Training	0.97	[illegible]	[illegible]	10.15	(8)
Heat-stress Pilots	[illegible]	[illegible]	3.95	4.20	(8)
C-135 Crew	[illegible]	[illegible]	[illegible]	5.23	(8)
C-141 Crew	[illegible]	[illegible]	2.56	4.32	(5)
Air Traffic Controllers	[illegible]	2.05	4.68	6.30	(8)
F-100/F-104 pilots	0.25	[illegible]/1.82	1.23	3.57/5.72	(7)
F-15/F-106 pilots	2.08	3.21	5.00	5.96	This study

mine; viz, active epinephrine levels are higher in the pilot training and heat-stress pilot groups, and air-traffic controller groups. Apparently however, fighter pilots engaged in ACM had more sympathetic activity than did fighter pilots engaged in lengthy flights without significant increases in G, i.e., the F-100/F-104 groups (Table IV). Hale *et al.* (4) have shown that catecholamine outputs are significantly increased in the summer months; however, since this study occurred during April, our data would not have been affected by this seasonal influence.

Correlation analyses were made between the percentage increase in catecholamines (postflight value-preflight value) and several aspects of the ACM (Table I). None were statistically significant; i.e., brief ACM was associated with as much increase in sympathetic activity as lengthy ACM. This finding may explain why some pilots were exhilarated by short-duration ACMs.

Catecholamine levels had returned to preflight levels in our second postflight samples—a mean time period of 3 h 55 min after each flight.

Stress: The physiologic stress responses of these pilots were quantified using the urinary metabolite 17-OHCS. As shown in Table II, ACM activity was associated with an increase in the level of 17-OHCS by 20% which was statistically significant (paired t-test; $p<0.01$).

Our preflight levels of 17-OHCS as found for catecholamines also were high in proportion to control values from other studies (Table III). Similarly, as determined with catecholamine levels, our non-ACM control values for 17-OHCS were high—greater by 67% when compared with those of the unstressed control group—thus suggesting some baseline shift upwards of resting values for both catecholamines and 17-OHCS in our ACM pilots.

This high level of 17-OHCS in our pilots during days of rest was considerably different from that found by von Werder and Ulbrecht (10) in F-104 pilots. They reported that excretion of "free urinary cortisol" was more than doubled on flying days compared with nonflying days.

Other Urinary Constituents: Urea, inorganic phos-

phate, sodium (Na), potassium (K), and Na/K ratios also were determined from the urine of these pilots. In the past, our USAFSAM laboratory found significant increases in all of these constituents, except for inorganic phosphate, in stressed populations (5-7). These increases had been considered related to the stress response of these individuals. In our study, however, we found reductions in most of these urinary constituents in our postflight pilots as compared with their preflight values (Table II). These reductions were statistically significant for some of the pilot groups for urea, inorganic phosphate, and potassium values (paired t-test). All of these constituents returned to preflight levels in our second postflight samples—except for potassium, which continued to decline, thus resulting in a significant increase in the Na/K ratio.

The reason for a reduction instead of the expected increase in these factors in our stressed pilots is not apparent; but our resting values were quite high compared with those in previous studies reported by our laboratory (Table III). Moreover, in this study, we have been unable to assess completely the effects of diurnal variation.

DISCUSSION

We had heard unofficially that the F-15 pilots were quite fatigued after ACM flights. It is well known that fatigue can initiate a stress syndrome. Consequently, we were concerned because stress can reduce performance and thus have a detrimental effect on the pilots' ability to fly ACMs.

The fact the ACMs flown by the F-15 pilots included long durations of peak G, as compared with the peak-G durations of the F-106 group, may have accounted for the increased fatigue in the F-15 pilots—if degree of fatigue is considered as the change in fatigue score resulting from ACM. Although fatigue score was not related to the duration of the ACM in the F-15 pilots, it was highly correlated in the F-106 groups. The F-15 pilots were apparently fatigued by short-duration ACM; but the F-106 pilots became exhilarated, and their fatigue scores were higher postflight than preflight. This exhilarating effect appeared to be unrelated to epinephrine release; epinephrine levels were not different between pilot groups. Also epinephrine release was not a function of ACM duration; increases in epinephrine were as great after short-duration as after long-duration ACMs. However, when G limits are removed from the F-15 and the same pilots fly these high-performance aircraft every day, fatigue may become a function of some ACM factor.

This rapid relative fatigue effect for the F-15 pilots is interesting, and may be the result of the "type of G" pulled in the F-15. Some pilots described the accelerative forces of the F-15 as different, more "positive," from those developed by other fighter aircraft.

The stress exhibited by the F-15 flyers (17-OHCS) was not significantly different from that of the F-106 pilots and would be classified as moderate—certainly *not* severe. The stress response of the pilots was not correlated to their fatigue, to their sympathetic activity, nor to the duration of ACM. A single brief ACM produced the same degree of stress response as did several ACMs of several minutes' duration.

The common denominator for all ACMs is the competition between pilots, and this was always exceptional. The need to win was always with the F-15 pilots, because they were expected to win. A tie was considered as a loss by them, and a triumph for the F-106. On the other hand, the F-106 pilots' greatest ambition was to "shoot down" an F-15. This type of furious competition probably elicited much of the physiologic responses during the ACM. Some of these catecholamine and 17-OHCS changes, attributed to the ACM, may be a function of diurnal variation which could not be completely eliminated in this limited study, i.e., this project was designed to detect large changes in these parameters during the ACM, which did not occur. The second postflight urine sample was used as a type of diurnal control, however, for it was collected in mid-afternoon over a period of time that the diurnal peak for 17-OHCS had been reported to occur (H. B. Hale, personal communications, 1976). Usually, the values associated with this second postflight sample had returned to near preflight values.

Possibly the most interesting aspect of this study is the high "resting" levels of all urinary constituents as compared with other stress-prone populations (Table III). The physiologic effects of this high level of resting sympathetic activity are not known, but an increase in heart rate and arterial blood pressure would be expected which could result in some moderate cardiac hypertrophy. On the other hand, the body may "reset" (adapt) its cardiovascular response to this high level of sympathetic activity and exhibit "normal" cardiovascular measurements. The high resting level of 17-OHCS would suggest that these pilots are possibly in a state of adaptation to the ACM environment. It would be interesting to determine the physiologic state of these pilots, and what duration of rest (vacation) would be required for fighter pilots to lose their adaptation to this unique environment.

In summary, we may conclude that, with the present G limits imposed on the F-15, pilots flying ACM are moderately stressed. This stress is not correlated with their sympathetic activity nor state of fatigue, and appears to be independent of the character of the ACM. Therefore, the fatigue experienced by the F-15 pilots during these ACMs—with imposed G-limits and speed, and flying against inferior aircraft, not on a daily basis—is not excessive. On the other hand, the ACM duration and degree of fatigue in the F-106 pilots are significantly correlated. This correlation is not a result of excessive fatigue, but of the fact that short-duration ACMs are exhilarating to the F-106 pilots.

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